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Music gestural skills development engaging teachers, learners and expert performers

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Abstract

This article presents a platform for learning theoretical knowledge and practical motor skills of musical gestures by combining functionalities of Learning Management Systems (LMS) and Serious Gaming (SG). The teacher designs his/her educational scenario that can be articulated by both theoretical and practical activities. The learner accesses online multimedia courses by using his/her LMS client which can be a computer, tablet orsmartphone and the serious game by using his/her computer and the motion capture sensors. During practicing, his/her gestures are compared in real-time with the expert gestures and s/he is evaluated both in terms of correct fingerings and kinematics. Finally, the platform offers a single profile for the learner for theoretical and practical activities.

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Keywords: Skills development; Musical gestures; Teaching; Learning; Gamification

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1. Introduction

By definition, the motor skills constitute an expertise that used to be transmitted in person, following the‘learning by doing’ concept. According to the ‘Dale’s Cone of Experience’ [1,2], people generally remember 70% of what they hear, write and say as well as 90% of what they do. From the Information and Communication Technologies (ICT) point-of-view, Learning Management Systems (LMS) and Serious Gaming (SG) constitute the most usual pedagogical instruments associated with learning. LMS is based on multimedia content (listening and reading) and interactive e-courses (speaking and writing), while only SG permits simulations in virtual environments. Nevertheless,the learning process occurs only by simulations based on mouse interactions rather than motion-driven narrative. Consequently, the key question is:

How can LMS and SG serve the ‘in-person’ transmission of expert gestural skills within a ‘learning by doing’ context and by engaging at the same time, teachers, learners and experts?

The main goal of the research presented here is the creation of an innovative platform, for the learning of musical gestures. The current state of the platform provides multimedia educational content that any teacher can publish. It also aims to transmit theoretical knowledge of musical gestures. Additionally, gamification aspects are also provided for learning expert know-how based on capturing, modeling and recognition of gestures, including finger motions, and real-time comparison between the performances of the expert and the learner. For these purposes, a series of online courses have been developed to support learning of basic elements of music theory, such as intervals, scales and chords, packaged using the SCORM standard. As far as the ‘learning by doing’ aspect concerns, a novel Intangible Musical Instrument (IMI) has been developed for capturing motions of the upper body part including fingers. Microsoft Kinect and Leap Motion Controller have been used for extracting Cartesian motion descriptors and inertial sensors for rotations. There is no physical contact with the sensors except for the two inertial sensors which are mounted on the wrists.

A gesture vocabulary with elementary piano-like gestures has been determined. The fingerings that the learners should perform are given by the musical score while his/her gestures are compared in real-time with those of the expert. The performance of the learner can also be manually communicated to the LMS. The presented platform can be used for formal learning, i.e. in music schools and conservatories using a real piano and hand gesture recognition, as well as for non-formal learning by using the IMI where both finger and hand gesture are recognized and mapped into sounds.

This paper is structured as follows. The next section outlines related research on the use of platforms for learning theoretical knowledge and/or practical motor skills. The following section describes our methodological approach by combining LMS and SG in order to serve the ‘in-person’ transmission of expert gestural skills. Hence, how the learner’s performance is evaluated by the system is presented in the final section.

2. State of the art

In recent years, cultural content is available on the web in various forms (documents, images, audio tracks, videos, collection items, learning objects, etc.), concern various topics (art, history, handicrafts, etc.), is written in different languages and is provided by different independent organizations (museums, archives, libraries) and individuals. Such projects that propose digital platforms and provide access to cultural material are Athena [3], ECHO - European Cultural Heritage Online Initiative [4], Europeana[5], etc. Another project called i-maestro [6], aims to build a multimedia environment for technology enhanced music education. This employs self-learning environments, gestural interfaces and augmented instruments promoting new methods for music training. SG is also used in the field of Cultural Heritage education because it offers advanced interaction and engagement. Such examples are Thiatro [7], a 3D virtual environment, which immerses the player into an exhibition and helps students learn about art history, or My Culture Quest [8], an interactive game which aims at collecting world objects to curate user’s exhibition.

However, the purpose of the aforementioned projects is not to combine both LMS and SG to serve the ‘in-person’ transmission of expert gestural skills within a ‘learning by doing’ context and by engaging at the same time, teachers, learners and experts. Below some definitions as well as the benefits of both LMS and SG are presented.

2.1. Learning Management System

LMS are computer based-platforms or systems that are used to facilitate educational processes. These processes may include the management and delivery of educational content, assessment procedures such as online quiz/exam taking with progress tracking, collaboration tools between the online learners and the teachers an higher education [9], etc.

Since LMSs are mostly web-based, they can take advantage of the benefits that the World Wide Web technology has and follow its evolution (e.g. HTML5, CSS3) which enables them to offer rich multimedia content like the one in [10]. Teachers can include multimedia enriched and also interactive content so learners can have the opportunity to enjoy a more pleasant and appealing educational process. The capability of distributing interactive content through the LMS opens up a whole new world of educational experiences such as SG, where learners can learn as they play.

2.2. Serious Gaming

SG is more and more used by public and private entities, educational institutions, companies for the effective trainings of their users. These digital tools are also of a high potential for skills acquisition since skills are acquired easier through simulations, and game mechanisms than just theoretical presentations. SG support learning and training in a variety of educational fields, such as formal and informal education; this is done for a wide range of target populations, ranging from children to adults [11]. The educational potential of games has been widely explored and highlighted by researchers within the wider research area of Game Based Learning [12,13,14,15]. This potential reveals empirical evidence that the educational use of games can actively and effectively support knowledge acquisition, perceptual and cognitive, behavioral, affective, motivational, physiological and social outcomes, and, to some extent, soft skills development [16].

Someadvantages of SG adoption in educational processes are also presented. Hainey et al. [17] suggest that games support constructive, experiential and situated learning; these are all aspects that the modern theories of learning suggest as central for effective learning. Games are also widely recognized as potentially adaptive to support the learning of procedures and gestures (and also of sequences of gestures, physical actions). In this flow, they are also widely adopted in professional training [18,19]. Research has proved that games promote extrinsic and intrinsic motivation [20] through the setting up of goals and rewards [21] and/or through a narrative context [22]. As Zap and Code [23] stated *'Video games possess at least eight characteristics that make them ideal environments for facilitating and promoting self-regulated learning. Games are: (1) interactive, (2) repetitive, (3) adaptive, (4) cumulative, (5) scaffolded, (6) affectively situated, (7) intrinsically oriented, and (8) based on both player-centered and game-based goals'* (p.738). Finally, there are many digital multiplayer games, which are not based on a competitive dynamic, but support collaboration among the players/learners.

Our ambition in this research approach is to combine the principles of a SG with the LMS and benefit within the SG of various LMS functions mentioned above. The LMS will be used as a tool to drive the SG' scenarios though the pedagogical aspects that provides e.g. a) depending on the user profile it establishes a sequence of objectives, b) it provides a list of contents linked to the educational objectives, c) it provides quizzes, etc. On the other hand, SG provides interaction based on real performance of the gestural skills, without the use of mouse or other devices. Also, both the 3D avatar and the real-time feedback guide the learner and make him/her aware of his/her mistakes.

3. Methodological approach

The innovative platform aims at facilitating access to the knowledge of the performers that constitutes musical Intangible Cultural Heritage (ICH) using democratized technologies that are easily accessed from the large public. Additionally, IMI is able to capture, model and recognize expert musical gestures (upper body including fingers) as well as to map them with sound. A special focus has been given to the design of a unified concept for learning, performing and composing with gestures.

To achieve the aforementioned, LMS will facilitate along with the SG, the educational processes of the platform. It will be used to realize the Pedagogical Plans into Educational Scenarios. It provides the ability to a teacher to create online courses and enrich them with all sorts of educational material such as documents, pictures, videos and event quizzes that can be used for assessing the learner's progress [24].A very useful education tool is the learning path. The learning path is a series of chapters which can contain any kind of resources (html pages, multimedia content, text, image etc.) but additionally has the option to enable requirements. The learner that engages with a learning path must complete successfully each step of the path, before advancing to the next one. At the same time, his/her progress on the path is monitored (time taken to complete the path, quiz scores etc.). This path can be exported to SCORM format and can be implement inside LMS [24].

When the teacher completes the theoretical part of the online courses, s/he can create the activities that the learner can perform by using SG within the IMI. After the learner finishes playing game activities, the result of his/her performance will be sent to the platform, updating his/her profile. This will give the ability to the teacher to be informed about the learner's performance and acquired gestural musical skills.

The next sections describe the pedagogical plan which contains the educational scenario that is implemented according to experts' and teachers' guidelines as well as the SG within the IMI, through which learners and performers can interact, learn and perform musical gestures.

3.1. Educational scenarios for learning theoretical knowledge

The educational scenarios are available through the LMS. Although it is an on-going process, the following activitieshave been implementeduntil now, with the help of the experts:

- Activity #1: Familiarization with the platform
- Activity #2: Theory of music
  - Elementary level
  - Intermediate level

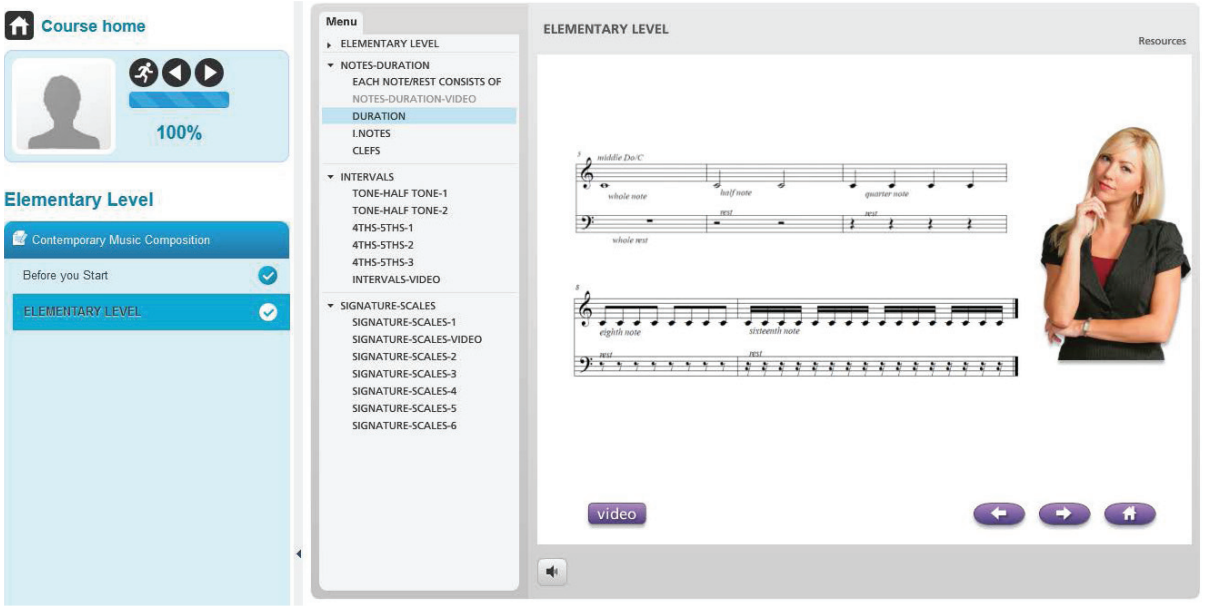

Fig. 1. Activity #2: Theory of music, for the elementary level.

Fig. 2.Intangible musical instrument.

The first activity includes some introductory description about the technology and the sensors to the learners. At the end of this activity learners will get familiarized with the main functionalitiesof the platform, which will be used during the next activities. The second activity presents the theory of music and has two levels, elementary and intermediate level. The elementary level (Fig. 1)refers to beginners and presents to learners a basic theory of music, such as notes, duration, intervals, scales, etc. The intermediate level is for advanced learners, and presents triplets, ornaments, dynamics, chords, etc. At the end of these activities, the learner will get familiar and know the theory of music that s/he has attended. The educational material in all activities include slides with texts, audio resources, videos as well as some exercises/quizzes in the end of each lesson.

3.2. Serious Gaming for learning motor skills through the IMI

After finishing with the theoretical activities in LMS, the learner has the ability to practice by using the SG and the IMI. The IMI setup is a construction made of Plexiglas, shaped so as to look like a table on which the learner and/or performer can put his/her hands (Fig. 2).

The IMI captures the gestures using depth cameras for the upper body (Microsoft Kinect [25]) and for finger movements (two Leap motion Controllers [26]). Additionally, inertial sensors (IGS Animazoo motion capture suit [27]) compute rotations of the wrists. By combining these data, we have an accurate tracking of the upper body part including the fingers. By capturing the 3D positions of the upper-body joints, we get the bigger picture of how the body moves in order to produce the sounds. Making the assumption that the whole body is active to a certain extent in the production of a sound, recording the whole kinematic chain allows us to have a complete understanding of the gesture. In piano playing for example, expressivity information is contained in the whole upper body motion and not exclusively in the fingers. Therefore, by capturing the real musical performance of experts, we are able to analyse them offline and compare sets of similar gesture repetitions. There are three types of gestures that we use in the analysis, the first type is the effective gesture, which is a sound producing gesture, the second type is accompanist gesture which is inseparable from the former gesture and finally, the last type is called figurative gesture which is symbolic and communicative [28].

This prototype setup is integrated into a SG framework where the learner is assessed by the system. The musical game contains two gesture activities and a final challenge. In the first two activities, ‘observe’ and ‘practice’ phase are also being included. In the ‘observe’ phase the learner can observe the video of an expert performing a musical gesture (Fig. 3a).

a b

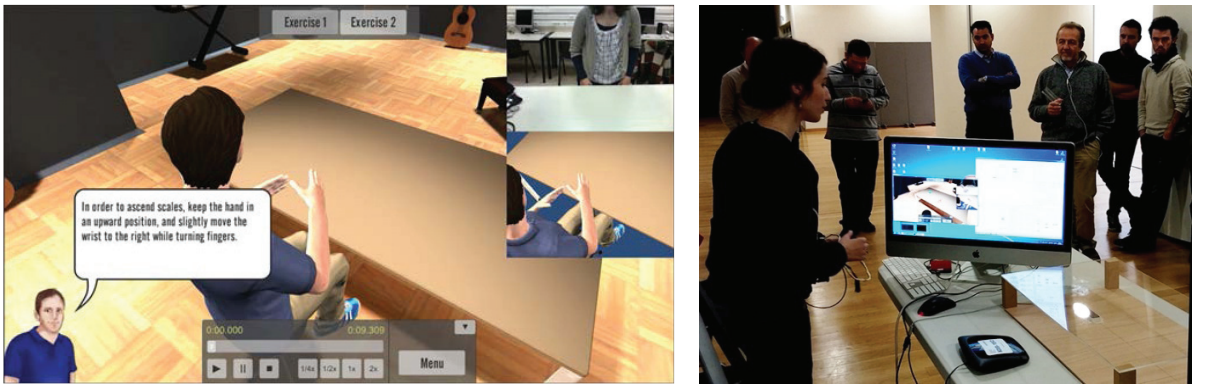

Fig. 3.(a) Observe Screen: 3D Expert Avatar (Big Central Window), Animation Controller (Bottom Centre), Expert Video (Top Right), Close-up Expert Hands (Centre Right); (b) 3D platform with the IMI setup.

At this point, the musical gestures that are considered in the vocabulary and being performed by using SG and IMI, are only effective gestures:

- *ascending* and *descending scales* will help the learner and/or performer understand the procedure of moving on the IMI and give him/her a sense of motion
- *ascending*and *descending arpeggios* involves fingering in order to play the musical sequence (this technique involves a more flexible and precise gesture since it involves fingers)

In the 'practice'mode, the learner imitates the gestures introduced by the virtual expert in the 'observe'mode (Fig. 3b). The performance takes place in a room, which looks like a recording studio with several musical instruments. Explicit (fingerings to notes, e.g. ascending arpeggio) and implicit (dynamic temporal correspondence and warping between gesture and musical excerpts, e.g. ascending scale) mapping sound to gestures are supported by the IMI. The final challenge for gestures includes *sequential ascending/descending scales* and *sequential ascending/descending arpeggios* as well.

4. Evaluation of learner performance

The musical gestures that are mentioned in the vocabulary are mapped into sounds that corresponding to the perceptual meaning of gesture. One of the most important aspects of this game is to evaluate the performance of the learner. In order to achieve this challenging task, gestures of the learner avatar and expert avatar are compared by using a Hidden Markov Model (HMM)-based algorithm [29,30]. This approach uses multiple-level inference and not only compares absolute positions but also evaluates more complicated features. The evaluation function is capable of providing not only final score but also instant evaluation, which will give instant feedbacks to the learner while s/he performs the musical gesture.

The evaluation method of the learner performance depends on the different musical gestures that s/he has performed. For ascending and descending arpeggios, the learner is assessed on the similarity between the score's note sequence and the one s/he just did. So the following formula will give his/her score:

$$Score = \frac{\#correct\_fingerings}{\#total\_fingerings} \quad (1)$$

For ascending and descending scales, a score is computed from the differences between the expert and learner's performance. So the evaluation of the learner will be based on the Euclidean distances between his/her timely warped gesture and the gesture of the expert only for the axe X, where n the number of the expert time stamps:

$$Score = \frac{\sum_{t=1}^{n} \left| \left(x_{RHand}^{Learner} - x_{LHand}^{Learner} \right) - \left(x_{RHand}^{Expert} - x_{LHand}^{Expert} \right) \right|}{n}, \quad (2)$$

This means that while the learner is performing the expert gestures, s/he tries to attempt to get close enough to the gesture model so as the sound is played back like the expert's sound one and at its original speed. Apart from the optical feedback, the resulting sound is the sonic feedback given to the learner in order to adjust his/her gestures to the expert's one.

5. Conclusion and perspectives

In summary, this paper presented a unified platform for achieving theoretical knowledge and practical motor skills in music, by providing a unified user experience for learning expert musical gestures and performing gestures. The platform extends existing components of Learning Management Systems by combining Serious Gaming functionalities in a unified way, by engaging teachers, learners and experts. Online educational content has been created, with the help of teachers in order to introduce notions of musical gestures and the theory of music. Moreover, the learner has the possibility to practice in the game, by using the Intangible Musical Instrument and performing musical gestures. This instrument has been trained with the expert gestures by using motion capture sensors. When the learner performs the same gesture, s/he receives a score according to the distance between his/her gesture and the reference model of the expert.Additionally, the proposed unified platform permits players to acquire musical knowledge and gestural skills through 'learning by doing' principles and can be considered as a mean of preservation of the musical heritage without any risk of destructing the tradition.

Our future work will be to implement an 'augmented' music score in the 3D game, which will facilitate access to the knowledge of the expert. It will provide gestural annotations of the most essential static and dynamic phases of his/her movements for given music measures from the music score. Finally, more educational scenarios in LMS and more activities in SG as well as further improvements of recognition, mapping and evaluation algorithms will be implemented.

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